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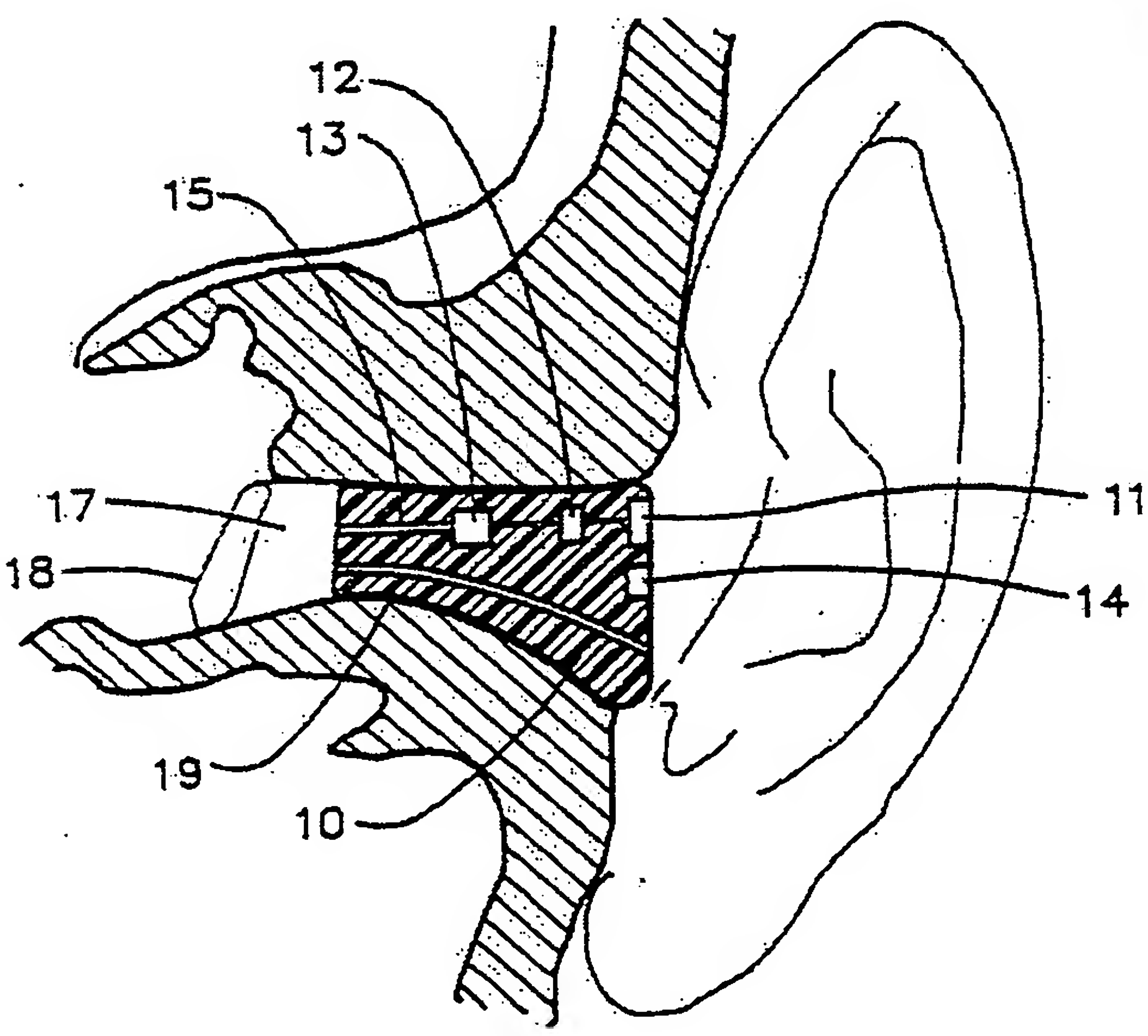
(54) Title: METHOD AND APPARATUS FOR REDUCING ACOUSTICAL DISTORTION

(57) Abstract

A method and apparatus for reducing distortion of an acoustical waveform produced by an acoustical output assembly or transducer, which could be an in-the-ear hearing aid. The transducer (11-14) is located within a composite which interacts with interfering waveforms. The composite comprises a plurality of microspheres (4) located within a polymeric matrix (2, 10). The microspheres can be selected from a group consisting of ceramic, glass, mineral and phenolic resins. The microspheres also have a mean diameter in the range of 5 to 5000 microns and can comprise 5 to 75 volume percent of the total composite. The polymeric matrix is selected from a group consisting of silicones, polyvinyls, acrylics, polyolefins, polyamides, polyesters and polyurethanes. The composite surrounding the acoustical output assembly can be shaped in the form of the transducer or output assembly and can be formed by injection molding or a slurry mixture.



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METHOD AND APPARATUS FOR REDUCING ACOUSTICAL DISTORTION

Field Of The Invention

This invention relates to a method and apparatus for reducing acoustical distortion of the output of an electro-acoustical transducer.

Background

All electro-acoustic transducers provide some degree of undesired change in acoustical waveform, i.e. distortion. Distortion is commonly divided into three types, i.e. frequency distortion, amplitude distortion (harmonic distortion) and phase distortion. Harmonic and phase distortion are particularly troublesome when the output acoustical transducer is located in a confined space or cavity, for example, in a hearing aid, sound head set or telephone receiver. Often the cavity has a "tuned" frequency and the materials in the cavity have resonant frequencies which, when coupled with the waveform from the transducer, result in peaks or spikes in the waveform corresponding to harmonic frequencies of the waveform, i.e. harmonic distortion. Additionally, phase shifts in the waveform can occur which produce distortion and also result in harmonic distortion where the resonant peaks persist for a period of time after the desired pulse. These effects can be heard by the listener as an annoying ringing.

With amplified hearing devices, such as hearing aids, the input signal is amplified so that the wearer of the aid receives an amplified signal which should correspond to the waveform of the input signal. However, noise and other extraneous signals are also amplified which create a problem of clarity and make it difficult for the wearer of the aid to "focus" on the desired sound. It has recently been found that much of the difficulty associated with focusing is due to the

presence of harmonic distortion in the amplified signal. Minimizing harmonic and phase distortions provide much greater clarity in the amplified sound and allow the listener using the amplification device to more readily focus on the desired sounds.

Feedback to the input transducer can also be a problem with devices such as hearing aids in which the input transducer is located in close proximity to the output transducer. The amplification of such feedback or resonance waves can result in "ringing" which can be unpleasant to the wearer of the hearing aid. Additionally, in the real world, the amount of usable gain available with a hearing aid varies depending upon the complexity of the signal being amplified. H. C. Schweitzer, Hearing Instruments, Volume 37, Nos. 1 and 2, 1986. Consequently, distortion can result in a lower output of the hearing aid and, therefore, a lower usable gain available for amplification.

To date, efforts to remedy the problems associated with lack of clarity and distortion in amplified signals have primarily focused on modifications in the electronic components and in physical placement of such components. The effect that materials of construction might have were considered in the past but were not found to be significant. It has been reported that: "Ear mold material was once considered a factor in the acoustic performance [of] ear molds. Except for the way in which the material might influence the tightness of the seal in the ear canal, it appears insignificant acoustically." S.F. Lybarger, "Earmolds", Handbook of Clinical Audiology, J. Katz, Editor, 1972, The Williams and Wilkin Company. Materials such as sintered pellets, mesh screens, lamb's wool and cotton have been used as acoustic obstructions (filters) in the earmold and earphone tubing or earhook to increase acoustic

resistance to modify response peaks. Hearing Aid Assessment and Use in Audiologic Habilitation, William R. Hodgson, Editor, 3rd Ed. p. 85 and p. 93 (1986). These obstructions, however, can cut down gain and output and can add distortion at higher acoustic pressures.

Although great advances have been made in providing electronic components which reduce distortion and improve clarity, lack of clarity in the output of acoustical transducers and difficuties associated with focusing on sounds continue to be problems. Consequently, there is a need for methods and apparatus for minimizing the distortions which can occur when acoustic waveforms are generated particularly in a confined space.

It has now been found that the above-described problems associated with harmonic distortion and feedback can be minimized by the use of a plurality of microspheres located in relation to the output transducer to interact with interfering waveforms. When the microspheres are used, a significant decrease in the total harmonic distortion is achieved particularly when the transducer or its output waveforms are in a confined space, such as an ear canal. Additionally, when the microspheres are used in the shell or housing to contain the input and output transducers, amplifier and associated electronics, significant reductions in total harmonic distortion and feedback are observed.

Both solid and hollow microspheres are well known as fillers in the plastics industry. They are commonly used as extenders and the hollow microspheres find application where it is desirable to reduce the weight of the polymeric product and improve stiffness and buoyancy. However, the reduction in distortion of

acoustic waveforms is totally unexpected in view of the reported acoustical properties of cellular polymers. As set forth in the Encyclopedia of Polymer Technology:

> "The acoustical properties of polymers are altered considerably by their fabrication into a cellular structure. Sound transmission is altered to only a minor extent since it depends predominantly upon the density of the barrier (in this case, the polymer phase). Cellular polymers are, therefore, very poor materials to use by themselves in order to produce sound transmission. They are quite effective in absorbing sound waves of certain frequencies (24). Materials with open cells on the surface are particularly effective in this respect."

Encyclopedia of Polymer Science and Technology, Herman F. Mark, Editor, 1970. As set forth in Volume 12, page 716, of the same series, "open-celled foams provide good sound deadening whereas hard, closed-cell foams have only slight absorption"; and on page 706, "since widespread friction of the air in the foam is important, closed-celled foamed polymers are in general not suitable for air-borne sound absorption." Accordingly, there is no suggestion in the known art of the advantages of the instant invention.

<u>Summary Of The Invention</u>

In one embodiment, the instant invention comprises a method for reducing acoustical distortion of an acoustical waveform produced by an electro-acoustical transducer. The method comprises providing a plurality of microspheres adjacent to the transducer to interact with interfering waveforms.

In another embodiment, the instant invention comprises a method for reducing acoustical distortion of an acoustical waveform produced by an acoustical transducer. The method involves placing the transducer within a composite which comprises a polymeric matrix and microspheres.

In another aspect, the instant invention comprises a method for reducing distortion in an in-the-ear hearing aid having an input transducer, an amplifier and an output transducer. The method involves encasing the transducers and amplifier in a shell which comprises a polymeric matrix containing microspheres.

In a further embodiment, the instant invention involves an acoustical output assembly having a housing which contains a) a means for producing an acoustical waveform, and b) a plurality of restrained microspheres.

In a still further embodiment, the instant invention involves an in-the-ear hearing aid which comprises a microphone to convert acoustical waveforms to electrical waveforms. The microphone is connected to an amplifier to amplify the electrical waveforms and supply the amplified waveforms to a receiver electrically connected to the amplifier. The amplified electrical waveforms are converted to acoustical signals by the receiver. The microphone, amplifier, and receiver are located within a shell which is composed of a polymeric matrix containing microspheres.

Description Of The Drawings

Fig. 1 is a cross-sectional schematic representation of an acoustical output transducer with a microsphere composite proximately located to said transducer.

Fig. 2 is a cross-sectional schematic representation of an in-the-ear hearing aid having a shell comprised of a matrix/microsphere composite.

Detailed Description Of The Invention

The terms "acoustical output means", "output transducer" and "receiver" are used interchangeably herein to refer to devices for converting electrical waveforms to acoustical waveforms.

The terms "input transducer" and "microphone" are used herein to refer to devices for converting acoustical waveforms to electrical waveforms.

It has been found that acoustical distortion particularly due to harmonic distortion can be decreased by placing microspheres so that they interact with potentially interfering waveforms. Significant improvements in clarity of sound produced with, for example, an in-the-ear hearing aid can be obtained. The decrease in total harmonic distortion obtained provides a greater useful gain in the devices. Also, the "focus" of the listener to the desired sound is greatly improved. While not wishing to be bound by the theory, it is believed that the microspheres act to "break up" standing waves and prevent build up of transient nodes.

The microspheres useful in the instant invention are materials which are commonly used as fillers in the plastic industry. The microspheres can be solid or hollow and can be made of a variety of materials, e.g. siliceous, ceramic, glass, polymeric and minerals such as silica and alumina. Depending upon whether the microspheres are hollow or solid and the material of construction, the diameter of the microspheres can range from about 5 up to about 5000 microns. Solid glass microspheres can be manufactured from a variety of glass types, for example A-glass. The silicate-

based microspheres have compositions which can be modified with organic compounds. These are commonly supplied as hollow microspheres. The polymeric materials can be formed from thermoplastic as well as thermoset resins. Commonly, phenolic thermoset resins are used to prepare these materials. Ceramic microspheres are commonly alumino-silicate ceramics although other ceramic compositions can be used. It is also contemplated that objects with shapes other than spherical, e.g. rectangular, cubic, etc., as well as objects with sizes greater than 5000 microns, can be used to reduce harmonic distortion and increase the clarity of sound. For ease of fabrication and commercial availability, the smaller size spheres are preferred.

In the instant invention, it is preferred that hollow microspheres be used. Preferably the microspheres have a diameter of about 5 to about 1000 microns. More preferably, the diameter of the microspheres is between about 10 and about 200 microns. Normally the microspheres are produced with a distribution of sizes. When the microspheres are used in an in-the-ear hearing aid, it has been found that good results can be obtained with microspheres having a mean diameter between about 50 and about 100 microns and particularly about 70 microns. It is also preferred that hollow glass microspheres be used.

In the practice of the instant invention, the microspheres are placed so as to interact with interfering acoustical waveforms. It has been found that a reduction in distortion can be obtained when the microspheres are used to coat the inside surface of a housing containing an acoustical output transducer. The most effective location for the microspheres can be readily determined with minimal experimentation by a

skilled person. Normally, it is preferred that the microspheres be placed proximately to the output transducer, and most preferably that the microspheres substantially surround the output transducer. For a given amount of microspheres, the effect is normally maximized if the output transducer is substantially surrounded by the microspheres, i.e. that the microspheres be placed in proximity to at least four of the six sides of a rectangular transducer. Of course, it is contemplated that a pathway for the acoustical output is provided from the transducer. The microspheres can be used in the form of a coating of a housing, shell or transducer case as described hereinabove or can be included as a component in the housing or shell as in a telephone receiver housing or a hearing aid shell.

For convenience, it is preferred that the microspheres be contained in a polymeric matrix. The composition of the polymeric matrix is selected based on the end use according to the physical properties of the polymeric material and its formability. Also, the physical properties of the final composite comprising the matrix and the microspheres must be considered in view of the end use. For example, for uses such as in a telephone receiver, the polymeric material should be rigid and tough to provide the necessary structural integrity. In uses where the material will be in intimate contact with the human body, for example, an in-the-ear hearing aid, factors such as allergic response to the polymeric material or monomers and additives contained therein must be taken into account. For uses requiring a rigid, tough matrix, resins such acrylonitrile-butadiene-styrene (ABS), polystyrene, polyethylene, polypropylene, polyamides, polyamide-imides, polyesters, polyurethanes, etc., can be used.

These materials can be cross-linked or contain other fillers and additives in addition to the microspheres. Commonly for uses such as ear molds, more flexible materials can be used which can include silicones, polyvinyls, both hard and soft acrylics such as poly(methyl methacrylate) and the like.

The loading of the microspheres in the polymeric matrix depends upon the end use of the resulting composite material. Other things being equal, the extent to which disruptive signals are damped increases as the level of microspheres increases. Normally, the amount of microspheres in the polymeric matrix ranges from about 5 to about 75 volume percent of the resulting composite. However, as the loading level of microspheres in the polymeric matrix increases, there can be a detrimental effect on certain physical properties of the matrix, e.g. a decrease in tensile strength. Consequently, the physical properties which are required for the composite determine the upper level of microspheres which can be incorporated into the matrix. Additionally, at the lower levels of microsphere loading a decrease in the effect of the microspheres on the distortion can be observed. Therefore, sufficient levels of microspheres must be incorporated in order to obtain the desired results depending upon the amount of composite material which can be used. Therefore, if the polymer matrix/microsphere composite is used in combination with or as an insert in other materials which do not contain microspheres, it is ordinarily desirable to use higher loadings of microspheres to obtain the desired result. In ordinary operation in an in-the-ear hearing aid, it is preferred that the microspheres comprise between about 10 and about 50 volume percent and most preferably about 10 to about 45 volume percent of the polymer matrix/microsphere composite.

Normally when incorporating microspheres into a polymeric matrix, a coupling agent is used to assure effective bonding between the polymeric matrix and the microsphere. Ordinarily with siliceous microspheres, a silane coupling agent can be used to treat the microspheres prior to incorporation into the polymeric matrix. Any such coupling agent normally used for this purpose can be used in the instant invention. However, in the event the material is to be in contact with human tissue, the pharmacological effects of the material must be considered.

As is well known by those skilled in the art, other additives can be incorporated into the polymeric matrix. For example, other fillers to affect or modify the physical properties of the matrix material can be incorporated. Additionally, additives such as antioxidants, stabilizers, lubricants, mold release agents, etc., can be used as appropriate.

The matrix/microsphere composite can be formed into the desired shape by any method known in the art for such forming. For example, as appropriate, the composite can be injection molded, cast into a mold form, or milled. Selection of the appropriate molding process depends upon the polymeric matrix being used and the end use of the product. For example, if ABS is used as the housing for a telephone receiver, it is expected that the composite would be injection molded into the proper form. However, in the event that the final article is an in-the-ear hearing aid, it is expected that a mold of the actual ear canal would be prepared and the polymeric material, for example polymethylmethacrylate, would be cast into the appropriate shape using the female mold of the ear canal. The electronics, including the output transducer, would then be attached to the composite material.

In a preferred embodiment of the instant invention, the matrix/microsphere composite substantially surrounds the output transducer. By "substantially" is meant that the composite surrounds at least four sides of the transducer; however, a pathway is provided through which the acoustic waveforms produced by the transducer can travel. The location of the composite material in this relationship to the transducer acts to dampen distorting vibrations which occur as the result of the transducer continuing to vibrate after activation as well as harmonic waveforms which are generated by resonance in the surrounding space and other materials in the space. These vibrations can result in out-of-phase secondary signals which produce harmonic distortion and/or feedback to the input transducer. Preferably, the composite material is formed into a housing for the output transducer and, more preferably, serves as a housing or shell to encase the output transducer and associated electronics, including the amplifier and input transducer.

With an in-the-ear hearing aid it is preferred that the composite material be used as the material of construction for the shell of the hearing aid. However, it is contemplated that the use of the composite material can be limited to its location around the output transducer with other material serving as the shell of the hearing aid unit. It is also contemplated that, as described hereinabove, the composite can be used as a coating on the surface of the housing or shell. For a behind-the-ear hearing aid, the composite material can be used as the housing for the electronics and/or it can be located in the conduits which conduct the amplified signal to the ear canal, and/or it can be used in an ear mold which fits in the ear canal.

Referring now to Fig. 1, a schematic representation of a transducer 1 is depicted with a composite material 2 composed of a polymeric matrix 3 containing microspheres 4 dispersed throughout the matrix located proximately to the transducer. When the transducer is activated by an electrical signal passing through connector 5, acoustical waveforms are generated. Secondary signals produced as the result of the transducer 1 continuing to vibrate after activation are reduced by the composite 2. As depicted by dotted line 6, it is preferred that the composite substantially surround the transducer.

An in-the-ear hearing aid is schematically depicted in Fig. 2. The shell 10 is shown inserted in the ear canal. Within the shell 10 is contained an input transducer 11, an amplifier 12 and an output transducer 13. The transducers and amplifier are in electrical communication with one another. Optionally, the amplifier can be connected to a control means 14 which can serve to adjust the gain or output of the amplifier. Other electronic circuits and/or components can be incorporated as appropriate, but these are not represented. The output transducer 13 generates an acoustical signal into tube 15. These signals travel into the ear cavity 17 and impact on the ear drum 18. Commonly in such in-the-ear devices, a vent tube 19 can be provided to allow for equalization of pressure and minimize discomfort to the wearer. As depicted in Fig. 2, the polymeric matrix/microsphere composite is used to form the shell or housing of the hearing aid and serves to encase the electronic components, however, it is contemplated that the composite material can be used to simply surround the perimeter of the output transducer with another material used to form the remaining portion of the shell or housing. It is

preferred that the shell or housing be prepared from the polymeric matrix/microsphere composite. This serves to minimize harmonic distortion as the result of vibrations transmitted through the material. Also, it minimizes feedback which occurs as the result of transmission of acoustic signals from the ear cavity 17 through the vent tube 19 and to the input transducer 11 as well as leaking between the shell and the ear canal.

It has been found by spectral analysis that an electronic device (input and output transducers and amplifier) encased in poly(methyl methacrylate) without microspheres shows a phase shift accompanied by a time lag. This is thought to result from the combination of the applied signal adding with noise background in standing wave areas throughout the spectrum. In contrast, the use of microspheres in the poly(methyl methacrylate) matrix with the same electronic device was found to provide a signal which, while showing some small degree of phase shift, was approximate to the original signal. This effect reduces ringing and unwanted spikes thereby adding appreciably to the clarity of the amplified sound.

The polymeric matrix/microsphere composite can be prepared by methods well known to those skilled in the art. For example, when the matrix material is poly(methyl methacrylate), the shell can be prepared by slush molding by first preparing an impression of the cavity. A female cavity is then prepared to mirror the impression. Commonly, the acrylic used for slush molding the shell is a two-part catalyst cured system. The base material is fast polymerizing polymer commercially available in powder form and commonly used in the dental industry. The powder which contains the microspheres is mixed with methyl methacrylate monomer. The resulting slurry is poured into the mold and allowed to

cure. This can be repeated to build up layers of the acrylic polymer to the desired final thickness. Unreacted monomer can be removed by heating the resinous body in hot water.

The following examples are intended by way of illustration and not by way of limitation.

EXPERIMENTAL

For the following tests, four instruments were assembled on open face plates. Two of the instruments had B-1 response curves, 40dB ANSI gain and 109dB MPO using Knowles electronics 1739 receivers as the output transducers. The other two instruments were assembled to have the same B-1 response curves with 40dB ANSI gain and 117dB MPO using Knowles electronics 1912 receivers as the output transducers. Knowles electronics 1842 input transducers were used for all four instruments. The amplifiers were standard LTI 505 chips.

Four shells were made for the right ear, two prepared from poly(methyl methacrylate) without microspheres and two from poly(methyl methacrylate) containing 35 volume percent hollow microspheres. The microspheres were bubble type B 23/500 from 3M Company which are reported to have chemical properties similar to a soda-lime-borosilicate glass. The microspheres are reported to have a crush strength of at least 500 pounds per square inch (34 Bars). The diameters of the microspheres range from about 10 to about 140 microns with an average diameter of about 70 microns. The microspheres (35 volume percent) were mixed by tumbling for 5 minutes at room temperature with the methyl methacrylate polymer (65 volume percent). The poly(methyl methacrylate) used was Audacryl RTC polymer grade 650 Z 2064 from Esschem Company having a reported

molecular weight of about 400,000 to 500,000. Two parts by volume of the polymer-microspheres mixture were mixed with one part by volume methyl methacrylate monomer. The resulting mixture was stirred in a container for 30 seconds. The container with the mixture was then placed in a vessel for 2 minutes under 0.5 atmospheres pressure. The mixture was again stirred for 30 seconds and then poured into a mold cavity. The mixture was slushed and cured at room temperature until a matrix wall thickness of about 2.5 to 3.5 millimeters was obtained. The remaining mixture was poured from the mold cavity. The solid matrix was removed from the mold cavity and placed in a pressure vessel containing water at 180°F and allowed to cure under 20 pounds per square inch gauge pressure for 30 minutes. No additional heat was added to the vessel so that the contents of the vessel cooled during the cure time. The matrix was then placed in boiling water for 20 minutes to complete the cure. Each of the resulting shells was finished by grinding and buffing to be as identical as possible.

Testing was done on the Frey electronics "phonix" 5500Z electro-acoustic test set. Battery voltage was calibrated at 1.35VDC with the test box being leveled and calibrated to standards once every hour of use. Tubing length and coupler/aid positioning were duplicated to as close to identical positions as could be maintained. Each face plate was loaded to the shell, checked and run in the chamber. Volume controls were locked in "full-on" position. Electronics were changed after each test run to the next shell for a total cross check shell to shell, electronics to electronics. The tests were run according to ANSI S 3.22-1982 except as indicated in the following Tables.

The results of tests comparing material with microspheres to material without microspheres are given in Tables I through XII.

Table I

With Microspheres				Without Microspheres			
Aid Gain db	Total Harmonic Dist. %	Aid In dB	Freq. In KHZ	Aid Gain dB	Total Harmonic Dist. %	Aid In dB	Freq. In KHZ
4.5		70	0.100	8.0		70	0.100
15.5		70	0.125	12.0		70	0.125
17.5		70	0.160	14.5		70	0.160
22.5		70	0.200	19.5		70	0.200
26.0		70	0.250	22.5		70	0.250
30.5		70	0.315	24.5		70	0.315
34.5		70	0.400	26.5		70	0.400
38.0	10	70	0.500	27.5	8	70	0.500
40.5	13	70	0.630	29.5	19	70	0.630
41.0		70	0.710	30.0		70	0.710
41.5	7	70	0.800	30.0	12	70	0.800
43.0	13	70	1.000	32.0	23	70	1.000
44.5	8	70	1.250	34.5	18	70	1.250
46.0		70	1.500	35.5		70	1.500
46.5	19	70	1.600	36.0	22	70	1.600
39.0		70	2.000	38.5		70	2.000
39.0		70	2.500	38.5		70	2.500
37.0		70	3.150	36.0		70	3.150
35.0		70	4.000	34.5		70	4.000
35.0		70	5.000	33.5		70	5.000
21.0		70	6.300	21.0		70	6.300
19.0		70	8.000	10.5		70	8.000
3.0		70	9.999	3.0		70	9.999

Table II

With Microspheres				Without Microspheres			
Aid Gain dB	Total Harmonic Dist. %	Aid In dB	Freq. In KHZ	Aid Gain db	Total Harmonic Dist. %	Aid In dB	Freq. In KHZ
7.5		70	0.100	8.0		70	0.100
11.5		70	0.125	12.5		70	0.125
13.5		70	0.160	16.0		70	0.160
19.0		70	0.200	21.0		70	0.200
21.0		70	0.250	22.0		70	0.250
23.5		70	0.315	25.5		70	0.315
25.0		70	0.400	27.0		70	0.400
26.5	11	70	0.500	28.5	17	70	0.500
27.5	16	70	0.630	30.0	35	70	0.630
28.5		70	0.710	30.5		70	0.710
28.5	12	70	0.800	31.0	28	70	0.800
30.5	25	70	1.000	33.0	44	70	1.000
32.5	21	70	1.250	34.5	30	70	1.250
34.0		70	1.500	35.5		70	1.500
34.5	19	70	1.600	36.0	24	70	1.600
36.5		70	2.000	39.0		70	2.000
38.5		70	2.500	39.0		70	2.500
35.0		70	3.150	36.0		70	3.150
32.5		70	4.000	34.5		70	4.000
31.5		70	5.000	34.5		70	5.000
23.5		70	6.300	21.0		70	6.300
10.5		70	8.000	10.0		70	8.000
6.0		70	9.999	-1.0		70	9.999

Table III

With Microspheres				Without Microspheres			
Aid Gain dB	Total Harmonic Dist. %	Aid In dB	Freq. In KHZ	Aid Gain db	Total Harmonic Dist. %	Aid In dB	Freq. In KHZ
4.5		75	0.100	11.0		75	0.100
5.0		75	0.125	12.0		75	0.125
4.5		75	0.160	15.0		75	0.160
9.5		75	0.200	16.0		75	0.200
12.5		75	0.250	18.0		75	0.250
19.0		75	0.315	22.0		75	0.315
24.5		75	0.400	23.5		75	0.400
28.0	1	75	0.500	25.5	11	75	0.500
28.5	2	75	0.630	26.0	17	75	0.630
28.5		75	0.710	26.5		75	0.710
28.0	4	75	0.800	27.0	19	75	0.800
29.5	10	75	1.000	29.5	35	75	1.000
31.5	7	75	1.250	32.0	23	75	1.250
34.5		75	1.500	35.0		75	1.500
35.5	22	75	1.600	35.5	31	75	1.600
38.5		75	2.000	38.5		75	2.000
37.0		75	2.500	37.5		75	2.500
35.5		75	3.150	36.0		75	3.150
32.0		75	4.000	32.0		75	4.000
35.0		75	5.000	33.0		75	5.000
13.0		75	6.300	15.0		75	6.300
7.5		75	8.000	.5		75	8.000
8.5		75	9.999	4.5		75	9.999

Table IV

With Microspheres				Without Microspheres			
Aid Gain db	Total Harmonic Dist. %	Aid In dB	Freq. In KHZ	Aid Gain dB	Total Harmonic Dist. %	Aid In dB	Freq. In KHZ
14.5		75	0.100	9.0		75	0.100
16.5		75	0.125	13.0		75	0.125
19.0		75	0.160	15.5		75	0.160
24.0		75	0.200	19.0		75	0.200
27.0		75	0.250	21.5		75	0.250
30.5		75	0.315	23.5		75	0.315
34.0		75	0.400	25.0		75	0.400
36.5	41	75	0.500	26.5	37	75	0.500
39.0	41	75	0.630	27.5	45	75	0.630
39.5		75	0.710	28.0		75	0.710
40.0	40	75	0.800	28.5	49	75	0.800
41.5	46	75	1.000	30.5	55	75	1.000
42.0	38	75	1.250	31.5	44	75	1.250
42.5		75	1.500	31.5		75	1.500
42.5	35	75	1.600	32.0	35	75	1.600
44.0		75	2.000	34.0		75	2.000
44.0		75	2.500	34.5		75	2.500
42.5		75	3.150	32.0		75	3.150
40.0		75	4.000	30.0		75	4.000
40.5		75	5.000	30.0		75	5.000
27.0		75	6.300	17.0		75	6.300
7.0		75	8.000	7.5		75	8.000
3.0		75	9.999	3.5		75	9.999

Table V

With Microspheres				Without Microspheres			
Aid Gain dB	Total Harmonic Dist. %	Aid In dB	Freq. In KHZ	Aid Gain db	Total Harmonic Dist. %	Aid In dB	Freq. In KHZ
8.5		75	0.100	8.5		75	0.100
12.5		75	0.125	13.5		75	0.125
15.0		75	0.160	17.0		75	0.160
18.5		75	0.200	20.0		75	0.200
20.0		75	0.250	21.0		75	0.250
22.0		75	0.315	24.5		75	0.315
24.0		75	0.400	25.5		75	0.400
25.0	38	75	0.500	26.5	41	75	0.500
26.5	42	75	0.630	27.5	51	75	0.630
27.0		75	0.710	28.5		75	0.710
27.5	48	75	0.800	29.0	56	75	0.800
29.0	58	75	1.000	31.0	64	75	1.000
30.5	55	75	1.250	31.5	52	75	1.250
30.5		75	1.500	31.5		75	1.500
30.5	35	75	1.600	32.0	35	75	1.600
32.5		75	2.000	34.0		75	2.000
34.0		75	2.500	34.0		75	2.500
30.5		75	3.150	31.0		75	3.150
28.0		75	4.000	29.5		75	4.000
27.0		75	5.000	29.5		75	5.000
19.5		75	6.300	16.0		75	6.300
8.0		75	8.000	7.0		75	8.000
6.0		75	9.999	-2.0		75	9.999

Table VI

With Microspheres

Aid Gain dB	Total Harmonic Dist. %	Aid In dB	Freq. In KHZ
12.5		75	0.100
14.5		75	0.125
16.0		75	0.160
18.0		75	0.200
18.5		75	0.250
21.5		75	0.315
22.5		75	0.400
24.0	6	75	0.500
25.0	16	75	0.630
25.5		75	0.710
26.0	13	75	0.800
27.5	19	75	1.000
30.5	16	75	1.250
33.0		75	1.500
34.0	27	75	1.600
36.5		75	2.000
37.5		75	2.500
35.5		75	3.150
31.0		75	4.000
33.0		75	5.000
17.5		75	6.300
-2.5		75	8.000
-10.0		75	9.999

Without Microspheres

Aid Gain db	Total Harmonic Dist. %	Aid In dB	Freq. In KHZ
15.0		75	0.100
17.5		75	0.125
18.5		75	0.160
21.0		75	0.200
22.5		75	0.250
24.0		75	0.315
25.0		75	0.400
26.0	18	75	0.500
27.0	34	75	0.630
27.0		75	0.710
27.5	23	75	0.800
30.0	40	75	1.000
32.0	30	75	1.250
34.0		75	1.500
34.5	31	75	1.600
37.0		75	2.000
37.5		75	2.500
35.5		75	3.150
31.0		75	4.000
32.0		75	5.000
18.5		75	6.300
-3.5		75	8.000
-7.5		75	9.999

Table VII

With Microspheres				Without Microspheres			
Aid Gain dB	Total Harmonic Dist. %	Aid In dB	Freq. In KHZ	Aid Gain db	Total Harmonic Dist. %	Aid In dB	Freq. In KHZ
12.5		80	0.100	14.5		80	0.100
14.5		80	0.125	16.5		80	0.125
16.0		80	0.160	17.5		80	0.160
17.0		80	0.200	19.0		80	0.200
18.0		80	0.250	20.5		80	0.250
20.5		80	0.315	21.5		80	0.315
21.5		80	0.400	22.5		80	0.400
22.5	34	80	0.500	24.0	40	80	0.500
23.5	48	80	0.630	25.0	51	80	0.630
24.5		80	0.710	25.5		80	0.710
25.0	56	80	0.800	26.0	58	80	0.800
27.5	68	80	1.000	29.0	68	80	1.000
29.0	52	80	1.250	30.0	57	80	1.250
29.5		80	1.500	30.0		80	1.500
30.0	43	80	1.600	30.5	44	80	1.600
32.0		80	2.000	32.5		80	2.000
33.0		80	2.500	33.0		80	2.500
31.0		80	3.150	31.0		80	3.150
26.0		80	4.000	26.0		80	4.000
28.0		80	5.000	27.5		80	5.000
14.0		80	6.300	15.0		80	6.300
-2.5		80	8.000	-4.0		80	8.000
-11.0		80	9.999	-8.5		80	9.999

Table VIII

With Microspheres				Without Microspheres			
Aid Gain dB	Total Harmonic Dist. %	Aid In dB	Freq. In KHZ	Aid Gain db	Total Harmonic Dist. %	Aid In dB	Freq. In KHZ
4.0		80	0.100	11.0		80	0.100
4.5		80	0.125	12.0		80	0.125
4.5		80	0.160	15.5		80	0.160
10.0		80	0.200	16.0		80	0.200
13.0		80	0.250	18.0		80	0.250
19.0		80	0.315	21.0		80	0.315
23.5		80	0.400	22.0		80	0.400
26.5	21	80	0.500	23.5	37	80	0.500
27.5	35	80	0.630	25.0	49	80	0.630
27.5		80	0.710	25.5		80	0.710
27.5	41	80	0.800	26.5	60	80	0.800
30.0	63	80	1.000	30.0	74	80	1.000
30.5	43	80	1.250	30.5	57	80	1.250
31.0		80	1.500	31.0		80	1.500
32.0	36	80	1.600	31.5	41	80	1.600
34.0		80	2.000	34.0		80	2.000
34.0		80	2.500	34.0		80	2.500
31.5		80	3.150	31.5		80	3.150
27.0		80	4.000	27.0		80	4.000
30.5		80	5.000	30.0		80	5.000
10.5		80	6.300	11.5		80	6.300
-8.5		80	8.000	- .5		80	8.000
-10.5		80	9.999	-4.5		80	9.999

Table IX

Aid In dB	Freq. In KHZ	Total Harmonic Distortion % With Microspheres	Without Microspheres
75	500	13	14
75	630	12	15
75	800	12	16
75	1000	15	62
75	1250	27	24
75	1600	14	87

Table X

Aid In dB	Freq. In KHZ	Total Harmonic Distortion % With Microspheres	Without Microspheres
80	500	14	11
80	630	16	18
80	800	11	20
80	1000	14	69
80	1250	21	55
80	1600	27	92

Table XI

Aid In dB	Freq. In KHZ	Total Harmonic Distortion % With Microspheres	Without Microspheres
85	500	38	16
85	630	11	20
85	800	17	34
85	1000	16	74
85	1250	16	67
85	1600	63	91

Table XII

Aid In dB	Freq. In KHZ	Total Harmonic Distortion % With Microspheres	Without Microspheres
90	500	48	23
90	630	10	23
90	800	19	46
90	1000	20	67
90	1250	18	65
90	1600	55	84

While various embodiments of the present invention have been described in detail, it is apparent that modifications and adaptations of those embodiments will occur to those skilled in the art. However, it is to be expressly understood that such modifications and adaptations are within the spirit and scope of the present invention as set forth in the following claims.

What Is Claimed Is:

1. A method for reducing distortion of an acoustical waveform produced by an acoustical transducer located within a polymeric matrix said method comprising locating a plurality of microspheres in contact with said matrix to interact with interfering waveforms.

2. The method of Claim 1 wherein said microspheres are located in a coating on the interior surface of a housing which contains said transducer.

3. The method of Claim 1 wherein said microspheres are substantially dispersed in a composite.

4. The method of Claim 1 wherein said microspheres are located in a conduit which conveys said waveform from said transducer.

5. The method of Claim 3 wherein said composite comprises a polymeric resin matrix with said microspheres comprising from about 5 to about 75 volume percent of the total volume of said composite.

6. The method of Claim 1 wherein said microspheres have a mean diameter between about 5 to about 5000 microns.

7. The method of Claim 1 wherein said microspheres have a mean diameter between about 20 to about 200 microns.

8. The method of Claim 1 wherein said microspheres comprise a material selected from the group consisting of ceramic, glass, mineral and phenolic resins.

9. The method of Claim 6 wherein said microspheres are hollow glass beads.

10. The method of Claim 6 wherein said microspheres are solid glass beads.

11. The method of Claim 3 wherein said composite substantially surrounds said transducer.

12. The method of Claim 5 wherein said microspheres comprise between about 10 and about 50 volume percent of said composite.

13. The method of Claim 12 wherein said microspheres have a mean diameter between about 5 microns and about 5000 microns.

14. The method of Claim 12 wherein said microspheres are hollow glass beads with a mean diameter between about 10 and about 200 microns.

15. The method of Claim 5 wherein said polymeric matrix is selected from the group consisting of silicones, polyvinyls, acrylics, polyolefins, polyamides, polyesters and polyurethanes.

16. The method of Claim 15 wherein said polymeric matrix is a silicone or poly(methyl methacrylate).

17. An acoustical output assembly comprising a housing containing:

a) a means for producing an acoustical waveform; and

b) a plurality of restrained microspheres.

18. The assembly of Claim 17 wherein said microspheres are located within a composite material which comprises a polymeric matrix.

19. The assembly of Claim 18 wherein said composite material is coated on the inside surface of said housing.

20. The assembly of Claim 18 wherein said composite material substantially surrounds said means for producing an acoustical waveform.

21. The assembly of Claim 18 wherein said housing comprises said composite.

22. The assembly of Claim 18 wherein said microspheres comprise between about 5 and about 75 volume percent of said composite.

23. The assembly of Claim 17 wherein said microspheres have a mean diameter between about 5 microns and about 5000 microns.

24. The assembly of Claim 22 wherein said microspheres comprise a material selected from the group consisting of ceramic, glass, mineral and phenolic resins.

25. The assembly of Claim 17 wherein said assembly is an in-the-ear hearing aid; said housing comprises a composite material which comprises a polymeric matrix and between about 5 and about 75 volume percent of substantially dispersed microspheres; and said means for producing an acoustical waveform is an electro-acoustical output transducer said transducer being in

electrical connection with an amplifier suitable for amplifying electrical signals received from an electro-acoustical input transducer.

26. An in-the-ear hearing aid comprising a shell containing:

a) a conversion means for converting a first acoustical waveform to an electrical waveform;

b) an amplifier in electrical connection with said conversion means to amplify said electrical waveform; and

c) a means in electrical connection with said amplifier for receiving said amplified electrical waveform and producing a second acoustical waveform, said shell comprised of a sufficient amount of microspheres to interact with acoustical waveforms which interfere with said second acoustical waveform and to reduce harmonic distortion in said second acoustical waveform.

27. The hearing aid of Claim 26 wherein said shell consists essentially of a polymeric matrix containing between about 10 and about 50 volume percent of said microspheres.

28. The hearing aid of Claim 26 wherein said microspheres are hollow glass beads having a mean diameter between about 10 and about 1000 microns.

29. The hearing aid of Claim 26 wherein said microspheres are solid glass beads having a mean diameter between about 10 and about 1000 microns.

30. A behind-the-ear hearing aid comprising:

i) a housing containing:

a) a microphone means for converting a first acoustical waveform to an electrical waveform;

b) an amplifier in electrical connection with said microphone means to amplify said electrical waveform; and

c) a receiver means in electrical connection with said amplifier to convert an amplified electrical waveform to a second acoustical waveform, and

ii) a conduit attached to said housing to conduct said second acoustical waveform from said receiver means to an ear canal, the improvement comprising providing a plurality of restrained microspheres in proximity to said conduit to interact with interfering acoustical waveforms and reduce distortion of said second waveform.

31. An article for containing an acoustical output assembly said article formed by:

a) preparing a composite comprising a polymeric matrix and microspheres, said microspheres being present in an amount sufficient to reduce harmonic distortion of acoustical output from said assembly; and

b) forming said composite into the shape of said article.

32. The article of Claim 31 wherein said forming is accomplished by injection molding said composite.

33. The article of Claim 31 wherein said microspheres are present in an amount of about 10 to about 50 volume percent of said composite.

34. The article of Claim 31 wherein said forming comprises:

a) preparing an impression of a cavity into which said article is to fit and then forming a mold which mirrors said impression;

b) forming a slurry mixture comprising microspheres, polymer, catalyst and monomer;

c) introducing said slurry mixture into said mold to form a layer of said composite in said mold;

d) repeating steps b) and c) until the desired final thickness of said composite is obtained; and

e) removing substantially all the monomer remaining in said composite.

35. The article of Claim 31 wherein said composite comprises poly(methyl methacrylate) and glass microspheres.

36. The article of Claim 31 formed into a shell for insertion into a human ear.

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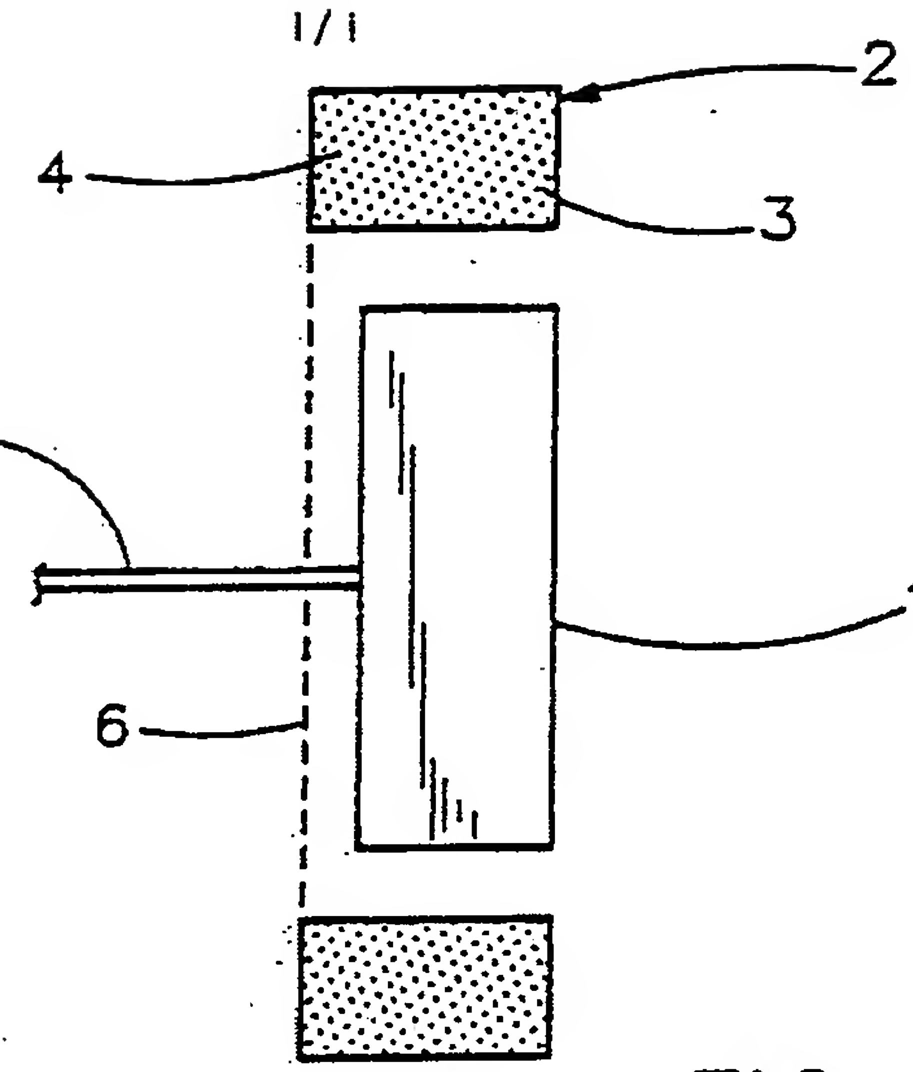

FIG. 1

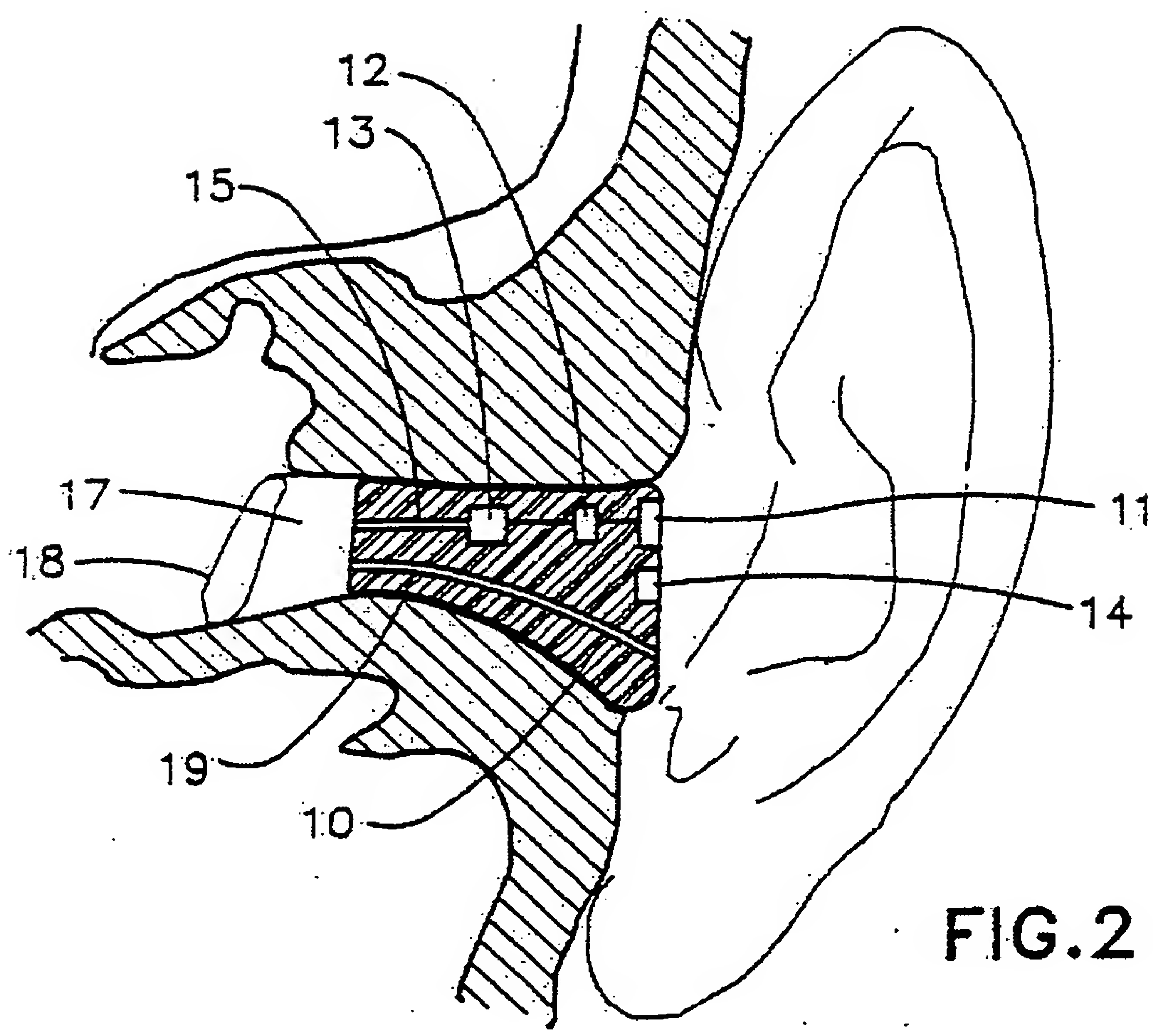

FIG. 2

INTERNATIONAL SEARCH REPORT

International Application No PCT/US87/02957

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. CL[4] - H04R 25/02, 1/28; B29C 45/00, 41/00
U.S. Cl. - 381/68.6, 69, 158; 181/286; 264/321, Digest 6

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
U.S.	381/68, 68.6, 68.7, 69, 150, 158 181/284, 286; 264/321, Digest 6

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
Y	US, A, 4,440,982 (Kaanders et al.) 03 April 1984. See column 1, lines 41-62.	1-36
Y	US, A, 4,079,162 (Metzger) 14 March 1978. See column 1, lines 8-16 and 66-68, column 2, lines 13-19 and 62-64, column 3, lines 1-6, column 4, lines 58-61 and column 6, lines 3-7.	1-36
Y	US, A, 3,755,517 (Clancy et al.) 28 August 1973. See column 4, lines 5-72 and column 5, lines 5-16.	31, 34, 36
Y A	US, A, 4,293,519 (Knappenberger et al.) 06 October 1981. See column 1, lines 48-66.	31 32-36
A	US, A, 2,802,764 (Slayter et al.) 13 August 1957. See column 1, lines 53-63.	1-36
A	US, A, 3,154,171 (Knutson et al.) 27 October 1964. See column 1, lines 25-26 and column 2, line 60- column 3, line 2.	1-36

(continued)

* Special categories of cited documents: [15]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
24 February 1988	05 APR 1988
International Searching Authority [1]	**Signature of Authorized Officer [20]**
ISA/US	Danita R. Byrd Danita R. Byrd

International Application No. PCT/US87/02957

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category*	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
A	US, A, 3,962,544 (Kobayashi) 08 June 1976. See column 4, lines 40-43.	1-36
A	US, A, 4,528,426 (Fatovic et al.) 09 July 1985. See column 2, lines 38-45.	1-36
A	US, A, 4,556,603 (Thosrud) 03 December 1985. See column 1, lines 14-16 and column 2, lines 19 and 23-26.	1, 11, 17, 26 30-31
A	US, A, 3,527,901 (Geib) 08 September 1970. See column 2, lines 60-62 and 66-68.	1, 17, 26, 30
A	US, A, 3,749,853 (Ely et al.) 31 July 1973. See column 3, lines 19-21.	1, 17, 26, 30
A	US, A, 4,620,605 (Gore et al.) 04 November 1986. See column 1, lines 11-12, column 2, lines 17-20 and column 4, lines 10-14.	1, 17, 26, 30
A	US, A, 4,463,049 (Kracke) 31 July 1984. See column 1, lines 6-7 and column 1, line 43 —column 2, line 10.	1, 17, 26, 30
A	US, A, 4,452,861 (Okamoto et al.) 05 June 1984. See column 1, lines 27-36.	34
A	US, H, T922,007 (Smith) 07 May 1974.	34
A	The PQ Corporation, Specification Sheet on Q-CEL 300 Hollow Microspheres.	2-16, 18-25, 27-29, 35
A	The PQ Corporation, Specification Sheet on Spherical Fillers.	2-16, 18-25, 27-29, 35
A	Q-CEL Microspheres-The Problem Solver, Brochure, The PQ Corporation.	2-16, 18-25, 27-29, 35
A	Blackburn et al., "Syntactic Foam," Modern Plastics Encyclopedia 1980-1981, page 155.	2-16, 18-25, 27-29, 35